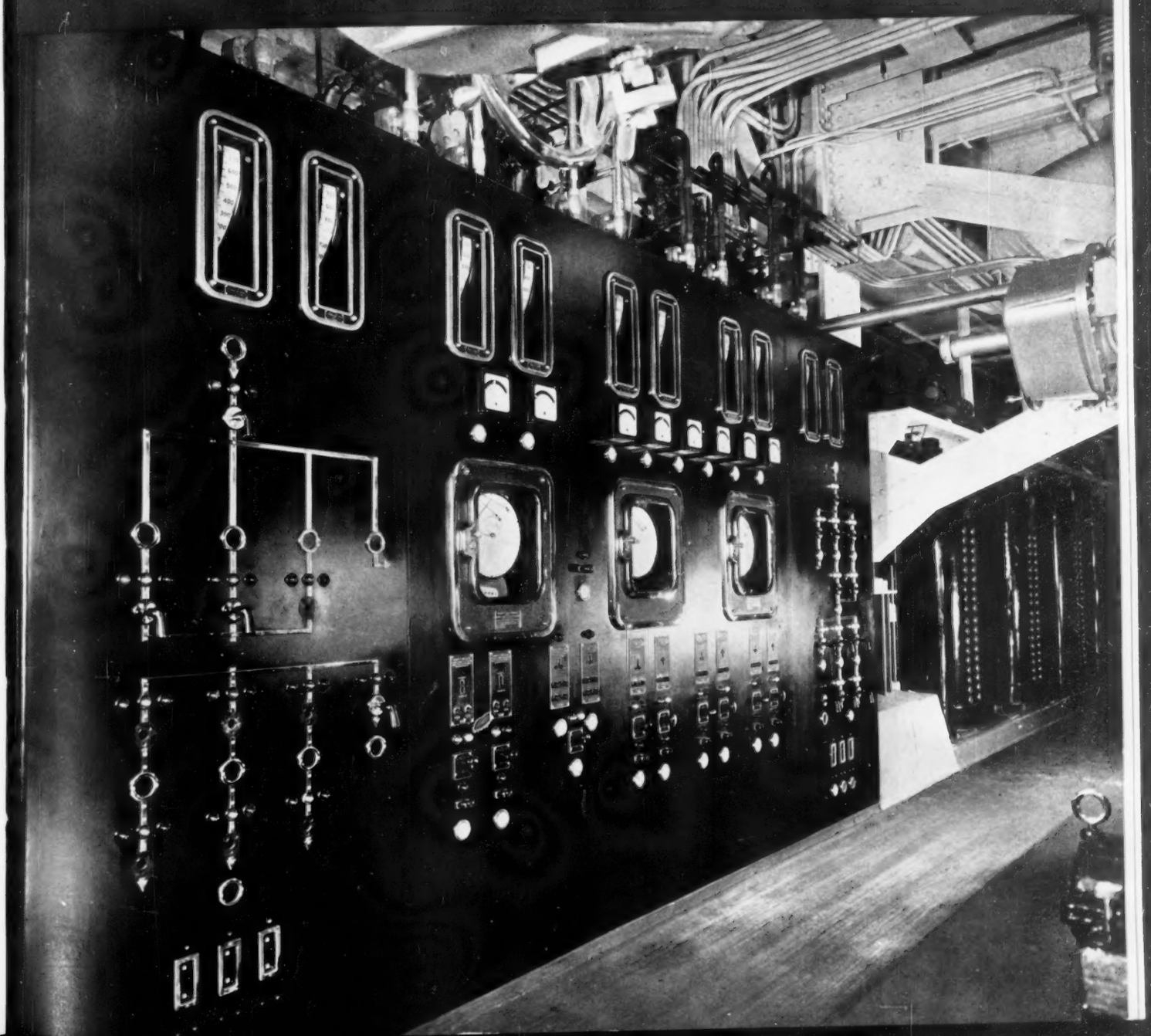
Instruments

THE MAGAZINE OF Measurement and Control

Vol. 11
JUNE
1938
No. 6



the NEW TAG RECORDING THERMOMETER

—Note the Improvements for Matching Precise Performance and Modern Style

- Visible-Record Pen Arm with Removable Capillary Fountain Pen.
- Positive Pen Lifter.
- Pen arm bracket supported by bearings at both ends—no backlash, no lost motion.
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- Safety Link for Over-range Protection.
- Interchangeable Tube System—the lifeline of the instrument. Tested, approved and standardized in stainless steel interchangeable parts.
- A turn of chart knob releases gripping fingers—chart slips over. Nothing to remove or lose.
- 12 Inch Chart — unusually long Pen Travel.
- Non-binding Chart Retainer.
- Cross Bar shields mechanism.
- A really convenient door latch—catches when door is swung to — Fastens when handle is pushed down.
- Time Line Indicator.

CONTINUING a steady succession of important developments which have marked the progress of TAG design from the first temperature controller installed in 1900—TAG now presents one of the outstanding instrument successes of the year—the new line of Recording Instruments with 10 and 12 inch charts.

A long record of faithful performance reflects these advancing instrument improvements. Primarily, it must be based on dependable precision to recommend this line of handsomely styled TAG Recorders to the service of temperature supervision in YOUR plant.

For itself and the other competent instruments in this new TAG Line, the Recording Thermometer illustrated here bespeaks the excellent agreement of its modern case styling with its advanced mechanical design.

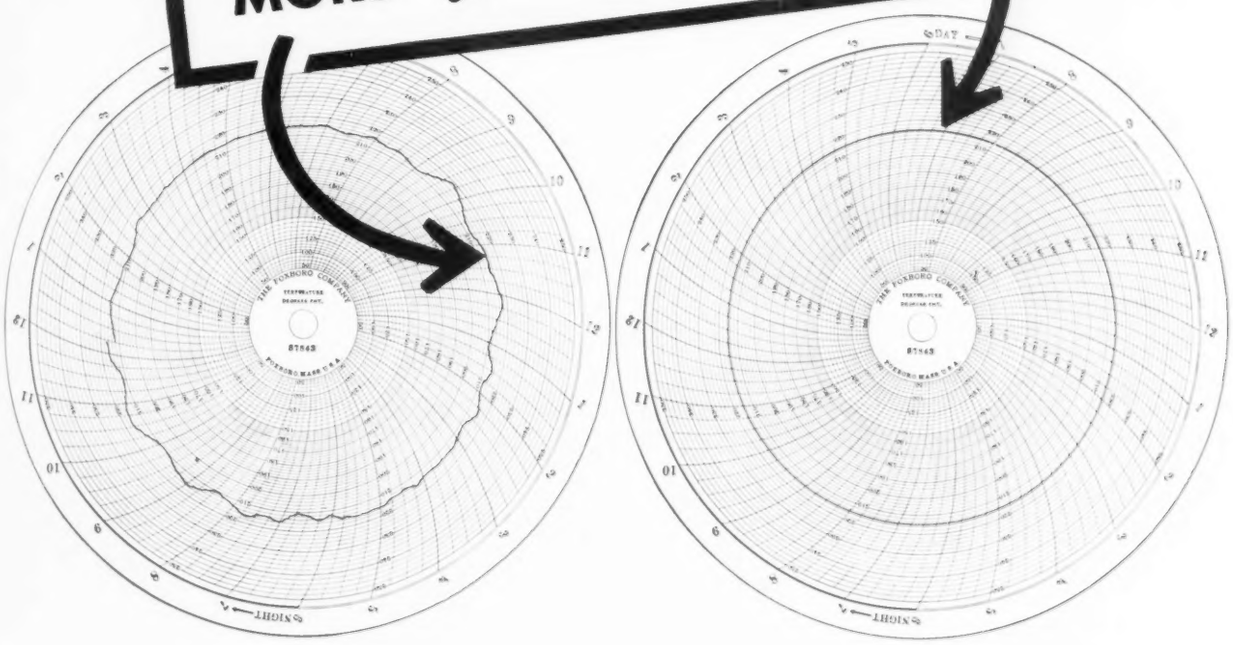
Check its many features and ask for your copy of the TAG Catalog No. 1060-I which illustrates and describes TAG's new Recording Thermometers and Recording Pressure Gages.

C. J. TAGLIABUE MFG. CO.

Park & Nostrand Ave's., Brooklyn, N. Y.

COMPARE THE RESULT!

THIS COST MORE *and* IS NOT AS GOOD AS THIS



Temperatures could not be maintained with throttling control. They needed fast-acting "Open and Shut" control. It was not a question of complicated refinements, but one of greater simplicity — as the charts proved.

When you have a temperature control job always think in terms of Foxboro "Open and Shut" Control first. It's the simplest controller . . . the first and only instrument to our knowledge designed as and successful as a fast open and shut controller. Moreover, Nature's laws made 65% of all temperature control problems easy and ideal for this widely used instrument controller. Included are dryers, kettles, ovens, cookers — jobs that have large heat capacity.

If you have jobs involving temperature, call in a Foxboro engineer. For more than a quarter of a century Foxboro has proved that 65% of all such control problems can be solved only by "Open and Shut" Control. You save in initial cost and get dividends during every hour of operation. Write for complete information. The Foxboro Company, 46 Neponset Avenue, Foxboro, Mass., U. S. A. Branch Offices in 25 Principal Cities.

35% of control problems cannot be handled by "Open and Shut" Control. To satisfy specific problems involving varying amounts of throttling range Foxboro perfected the Stabilog Controller. It does a perfect job on the 35%. Each type of Foxboro Controller has its definite place. Foxboro Engineers will gladly help you.

"Open and Shut"
Control Is Best In 65% of All Cases

FOXBORO REG. U. S. PAT. OFF. *Certified* **TEMPERATURE CONTROLLERS**

A REVOLUTIONARY NEW DESIGN
An OUTSTANDING IMPROVEMENT

ATTENUATOR

★ *4-Finger Beryllium Copper Contact*
★ *Molded Commutator Switching Mechanism*
★ *"Silent Spiral" Clock Spring Connector*
★ *Famous IRC Insulated Resistors*

An extremely low original noise level *maintained in actual service* is made possible in the new Type A-21 20-step Attenuator by its unique design.

The conventional stud type switch is replaced by a molded motor commutator with conducting segments of polished, hard-drawn copper molded in phenolic. Each finger of the multi-finger copper contact operates independently, insuring smooth, noise-free action. One series pressure contact is definitely eliminated by a "Silent Spiral" clock spring connector similar to that pioneered by IRC more than two years ago in the Type CS controls. Throughout, the Attenuator is constructed for long, trouble-free service.

The Attenuator is 2″ long by 2″ diameter. The attenuation range is linear from 0 DB to 45DB in steps of 2½ DB, tapering from 45 DB to infinity in the last two steps. It is made with or without detent action. Standard terminal impedances are 50, 200, 250 and 500 ohms. Other variations of ladder or step potentiometer networks are available. The unit is protected by a tight-fitting removable aluminum cover.

Write for catalog

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MAKERS OF RESISTANCE UNITS OF MORE TYPES, IN MORE SHAPES, FOR MORE APPLICATIONS THAN ANY OTHER MANUFACTURER IN THE WORLD

Instruments
THE MAGAZINE OF MEASUREMENT and CONTROL

VOL. 11 No. 6

JUNE, 1938

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INSTRUMENTS The Magazine of MEASUREMENT and CONTROL

M. F. BEHAR
EDITOR

IN THIS ISSUE

It is understandable by any schoolboy, that for every pound of steam generated by a continuous boiler a pound of water must be fed to the boiler, that a million pounds of steam per hour call for a million pounds of feed-water per hour, that if the header pressure is 1250 lbs./in.^{2} the feed-water must be pumped in at 1250 lbs./in.^{2} plus water head and pipe-friction-loss head and a little over for safety. Each of these things is elementary, but when you add them all up you have a real problem in measurement and control. Such is the Ford Motor Co.'s problem, and Power Superintendent Dulmage devotes his second article entirely to this aspect of Ford power plant instrumentation. *Pages 165-167.*

Since the "Williams on Hardness" Serial began in January, 1937, several readers have gratefully commented that Professor Williams "gives good measure" in each monthly instalment, by drawing inferences and setting forth various views. This month's instalment is an excellent example: his specific topic is the diamond pyramid indenter but he brings in the question of the validity of all "hardness numbers" based on ratios of load to indentation area. *Pages 168-170.*

"By a set of curious chances" (are you a G & S fan too?) Ralph Batcher, whose serial on cathode-ray oscillography has recently been concluded, was prevailed upon to contribute a sort of addendum—some hints on how to get microsecond accuracy in timing the spot traverse. *Pages 171-172.*

THE FRONT COVER

shows the boiler-feed and booster pump control board at the Rouge Plant of the Ford Motor Co.—which forms the subject of Dulmage's article.

A CERAMICS COURSE

is to be given at M.I.T. July 11-23, in which Temperature Measurement and Control is to be featured. *Instruments* urges members of the industry to attend. Write to Professor F. H. Norton.

COMBUSTION CONTROL

RECENT years have witnessed significant and important advances in the application of automatic-control systems to combustion processes.

Significant advances, because each development has in large measure represented a step forward—away from hit-or-miss empiricism and guess-work—toward the ideal of rational engineering. There's a heap of significance—of meaningfulness—in the new "united front" presented by designers of control systems, builders of fuel-fired equipment, and constructively-critical *users* of both.

Important advances, because they are gradually overcoming the prejudices of disappointed older executives who had been "oversold" in the early 'twenties. Wider acceptance of automaticity by this Old Guard is indeed of dollars-and-cents importance to American industries.

Just a year ago, when plans were being shaped for publishing the Tenth Anniversary Issue, the subject "Combustion Control" had a habit of popping up irrepressibly every time that heads were put together in efforts to perfect the menu to be served in that January 1938 issue. We finally decided to leave it out of that banquet and to give our readers, several months later, a second feast consisting of several courses of Automatic Combustion Control.

At last we can take pleasure in announcing the date of this special banquet. It will be next October's issue.

It will interest you to know that we've engaged a group of cooks belonging to a different "union." You remember that our Tenth Anniversary Issue was composed of "Decade of Progress" articles written by *you*—by users—each an authority on a general class of devices. For example R. J. S. Pigott, whose name has stood for fluid meter research since 1916, wrote the "Decade of Progress" article on metering and automatic control of industrial fluids, covering all commercial makes of meters and controllers. And what a tasty *blend* it was! In our October banquet, on the other hand, each single course will be *one* commercially-available system of automatic combustion control—and its cook will be the Chief Engineer (or other technical head) of the firm that makes it.

Our older subscribers will remember a special issue of *Instruments* composed according to this idea: the Calorimetry Issue of February, 1930, which won a warm welcome and still serves as a useful little handbook on calorimetry. We aim to put out an equally useful symposium next October—an issue that will serve as a brief modern automatic combustion control handbook.

BAILEY METER CONTROL SYSTEM

The Mark of

Effective Control

Process Control for sensitive, stable automatic control of temperature, pressure, liquid level, flow and other factors as applied to industrial processes. Responds to changes quickly, without overtravel or hunting. Ask for Bulletin No. 101.

Combustion Control that is simple but *complete* for providing economical operation of boilers of 200 h. p. and larger. Details in Bulletin No. 102.

Recorder-Controller

Boiler Meters for recording combustion conditions and guiding boiler operators. Described in Bulletin No. 44.

Multi-Pointer Gages for indicating factors such as draft, pressure, temperature and speed. These Gages are available with any number of pointers and any scale combination; in either the oil sealed bell or diaphragm construction.

Control Drive

Flow Meters for indicating, recording and integrating the flow of steam, water, sewage, air, gas and other fluids. Bulletins No. 39 and 300.

Recorders for pressure, temperature, drafts, liquid level and other factors.

C-3

BAILEY METER COMPANY

1041 Ivanhoe Rd., Cleveland, Ohio

NEW INSTRUMENTS

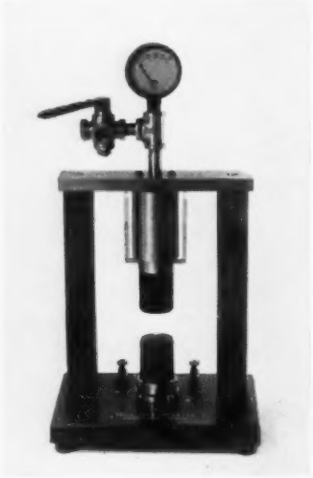
In this department we strive to report each month ALL the new devices for measurement, inspection, testing, metering and automatic control—in the form of concise technical descriptions.

When writing to manufacturers directly, please mention this department as your source of information.

Or write to Information Section, Instruments Publishing Company.

Tape Tester

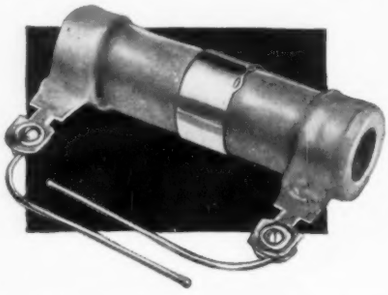
Design is modification of that by R. W. Chadbourn of Boston Edison Co. employed in laboratories where dielectric strength of cable-splicing and similar



materials must be checked. Electrodes permit clamping sample without wrinkles and center themselves with clearance for escape of gases at moment of breakdown. —*Mico Instrument Co., Cambridge, Mass.*

Fixed Power Resistors

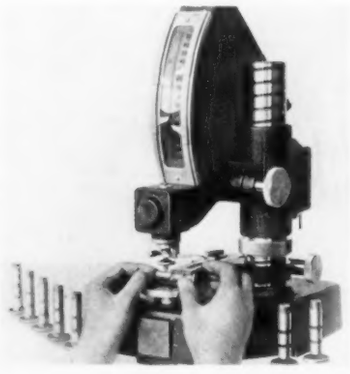
Wire-wound fixed power resistors are announced with a choice of two coatings: (1) for applications involving frequent overloads, inorganic cement type where-



by resistor may be operated at red heat without deterioration; (2) for protection against humidity as well as acid vapors or salt spray, varnish-coated type. Available in 5- and 10-watt varnished coating, and in 10- and 20-watt cement coating; resistance values from 1 to 50,000 ohms. —*Clarostat Mfg. Co., Inc., 285-7 N. 6th St., Brooklyn, N. Y.*

Comparator

"Microlux" comparator magnifies 1000× by combination of 10:1 mechanical lever and 100:1 optical lever. Indication is dark band across circular spot of green light on translucent scale in front of operator's eyes directly above work. Scale range is from +0.003" to −0.003"



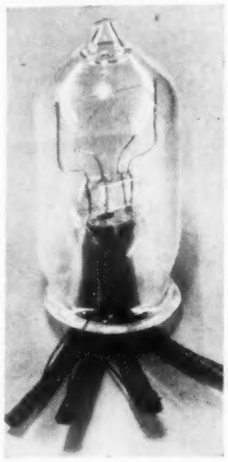
with zero-center and guaranteed accuracy is ±0.00002". Measuring anvils are readily changed; illustration shows standard round table with back-stop; scraped surfaces are provided at front and sides of base for mounting special fixtures.—*George Scherr Co., 120 Lafayette St., New York City.*

Multi-purpose Watch

Name "Multi-Chron" Two-button Time Study Watch is derived from plurality of functions: (1) timepiece of wrist-watch form with 15-jewel non-magnetic Swiss movement encased in stainless al-

loy; (2) stop-watch measuring seconds and fifths; (3) "tachometer" indicating miles-per-hour over known distance; (4) "time-out" watch with one button consecutively starting, stopping and again starting sweep second hand and other button for fly-back; (5) "telemeter" which gives distance by interval between light and sound from simultaneous sources.—*Jardur Import Co., 21 West 19th St., New York City.*

Vacuum . . . Thermocouples



Ranges from 1 milliampere to 10 amperes, in either contact or separate heater types. Prices from $3.00, quantity discounts.

Write for Bulletin "A"

AMERICAN Electrical Sales Co. Inc.
67 E. 8th St. New York, N. Y.

S-M-O-O-T-H VOLTAGE CONTROL for A.C. circuits

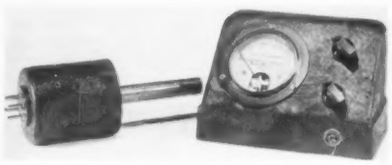
The Type "TH" Transtat is the new continuously variable auto-transformer regulator . . . the ideal voltage control for a.c. circuits. It offers high efficiency, good regulation, great flexibility and dependable construction at moderate cost. Standard types are available for controlling voltage to single-phase and polyphase loads rated 10 Kva. and smaller, 50 or 60 cycles, 115, 230 or 460 volts. May we send you bulletin 51-1 which contains complete data?

TRANSTAT
VOLTAGE REGULATORS

AMERICAN TRANSFORMER CO.
178 Emmet St. Newark, N. J.

Vacuum Gage

New "Model 10" employs same (Pirani) principle as do maker's other "Tru-Vac" gages (see *Instruments*, Sept. 1931, page 518; July 1934, page 148) but it



will read, in addition to extremely high vacuum, all intermediate and low ranges of vacuum employed in industrial processes; ten ranges are made available to user by means of a 10-point switch. Operation is from 110-volt 60-cycle supply. —*Continental Electric Co., Geneva, Ill.*

Wide-range Oven Control

A range of 100° to 500° F. is one of characteristics of new "Series 1000" controls for industrial ovens, employing "hydraulic action principle" (liquid-filled tube-system). Manufacturer states that while Type 1000 control (illustrated) has under normal conditions a fixed differential of 10° F., this differential may be reduced on many types of industrial ovens "by taking advantage of the natural anticipation in the oven through the proper location of the sensitive element." Rated capacity is 30 amp. 110 volt a.c., 15 amp. 220 volt a.c. and 1½ hp. 110 or 220 volt a.c. Types 1004 and 1006 are also available with a standard range of 100° to 300° F., with a corresponding reduction in the fixed differential to 8° F. All types in Series 1000 have single-pole single-throw contact action; d-t. d-b. on special order.—*White-Rodgers Electric Company, 1209 Cass Ave., St. Louis, Missouri.*

Antenna Ammeter

A new type of remote-reading antenna ammeter for use in broadcast stations is said to have been designed for maximum safety from failures due to lightning. Some features: the use of a shielded current transformer with a vacuum tube rectifier, linear scale; readings unaffected by modulation of transmitter; accuracy unaffected by as much as 50-ohm resistance in the pair of wires to the remote-indicating instrument; acceptance by the Federal Communications Commission. Various models are available with full-scale ranges from 1 to 80 amps.—*Victor J. Andrew, 7221 S. Francisco Ave., Chicago, Illinois.*

'JAGABI' RHEOSTATS MEET *Exacting* REQUIREMENTS

Because they provide fine adjustment and control of electric current over a wide range . . . because they are well made and durable . . . Jagabi Rheostats are selected and used by engineers, educators and research workers—especially those who are influenced by design, quality workmanship and performance. Bulletin 1515-I describes various standard and special types; write for a copy.

JAMES G. BIDDLE CO.
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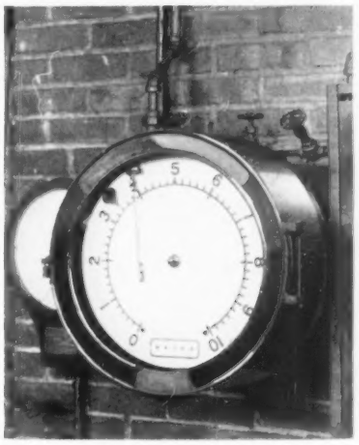
40% SAVED BY DETECTING LEAKS



A Cochrane Meter was installed to measure pump discharges in a water works system. A steady flow, recorded between 1 A. M. and 4 A. M., indicated leakage. This remedied, pumpage losses were reduced 40%. Savings were sufficient to pay for the meter **every two months.**

Cochrane Flow Meters give **accurate** measurements of fluid flow; dependable records and checks on operating costs. Write for illustrated bulletins.

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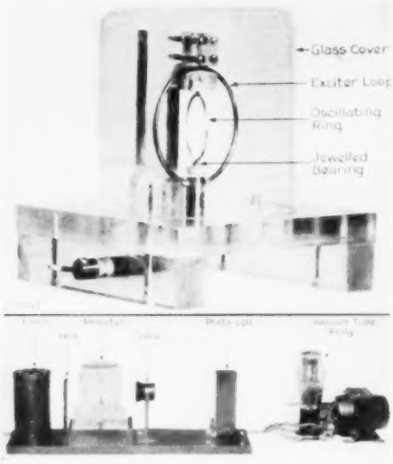
3120 N. 17th Street Philadelphia, Pa.

COCHRANE
FLOW METERS

Electrodynamic Ammeter

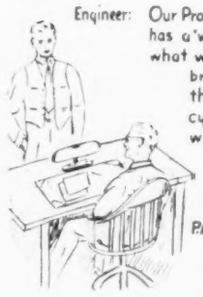
A jewel-bearing oscillating-ring electrodynamic ammeter is described as a standard of currents above one ampere, at high frequencies, since its performance



can be calculated from measurements of length, mass and time. It is used with currents from 3 to 6 amps over the 5 to 42 megacycle frequency range with an accuracy of ±1%. A high-frequency current flowing in the exciter loop imparts energy to the oscillating ring which then oscillates about the 90° position at a rate proportional to the current, and nearly independent of the frequency. Ring continues to oscillate until the energy is used up in air and bearing friction, usually 20 sec. or more. Lower ilustration shows method: A standard 1-sec. contactor on a primary frequency standard 1000-cycle clock actuates one pen of a two-pen chronograph, while a photoelectric oscillation counter actuates the other. Thus a tape chart is obtained on which appears a direct comparison of the period of the oscillating ring with time. New instrument has lower impedance than commercial instruments and therefore has less effect on the circuit into which it is connected.—*General Electric Co., Schenectady, N. Y.*

Fiber Microtome

Makes possible rapid preparation of extremely thin sections for those who study threads, plant stems, etc. Measuring drum is graduated in 10-micron divisions.—*Mico Instrument Co., Cambridge, Mass.*



Engineer: Our Product Development Dept. has a 'wow' in the making—what we need now is a vibration proof relay that will work on 800 cycles—do you know where you can get one?

P.A.: Sure thing: Struthers Dunn specializes on just such problems. I'll get in touch with them at once.

And you can't do better than getting in touch with Struthers Dunn, too, if you have a problem requiring relays!

J S D DUNCO

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Accurate set-ups of tools, rolls, blades, presses, etc. can be repeated quickly when Setting-up *Productimeters* are geared to spindle feeds or screwdowns to register the setting in thousandths. Once correctly made, the setting is read on the *Productimeter* and recorded to guide future set-ups for this job.

Model SMIB-5 above insures correct draft on steel mill rolls. Get our recommendations on set-up and counting problems.

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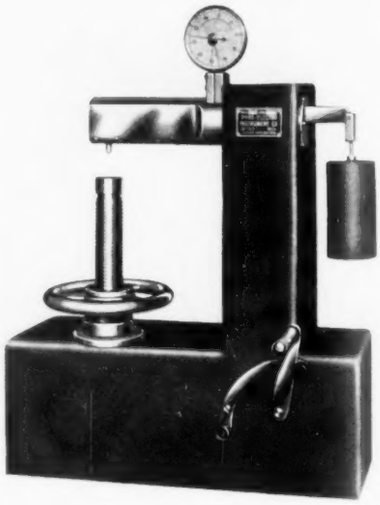
Two small screws suffice for attaching "Ste-Tre-Meter" automatic timer to a steel-treating furnace—the application for which it was specially developed by the manufacturer (a maker of high-speed steel tools). Distinctive features: zero-return accomplished either by foot lever at bottom or by hand lever at top; any number of target contacts may be positioned on periphery to ring bell and flash light or both at different pre-determined intervals; attachment by ring (barely visible at top of illustration) to furnace door whereby opening of door returns pointer to zero and holds it until closing of door starts cycle; two total time ranges (10 and 60 min.) on each instrument, with simple change-over from one to other. Ste-Tre-Meters are regularly available for 110-volt 60-cycle single-phase supply; also made for any other supply.—*J. Milton Luers, 3211 Bellevue Ave., Detroit, Mich.*

Internal Hardness Tester

"Model HT" horizontal internal tester is an "off-center tester" which may be used for internal testing on hubs, tubes, etc. as well as for all external testing.



Vertical capacity 8"; throat (internal reach) 6"; minimum I.D. 2⅛". Calibrated for diamond penetrator at 150 and 60 kg. and ⅛"-⅛" balls at 100 kg. Penetrator beam assembly is adjustable for testing at any point of the 6" internal reach. Dead-weight loading gives direct-reading "C," "B" and "A" scale numbers. Dial arrangement provides all scale readings with but one set of black numerals.—*Pyro-Electro Instrument Co., 7325 W. Chicago Blvd., Detroit, Mich.*

The All Purpose
AIR VELOCITY METER

"Alnor" Velometer

Instantaneous Direct Reading

No Timing
No Calculations
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For a Guaranteed accurate and reliable thermometer, which is very easy to read, specify:

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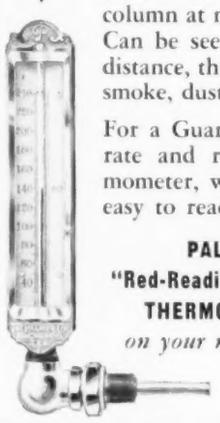
"Red-Reading-Mercury"
THERMOMETERS
on your next order.

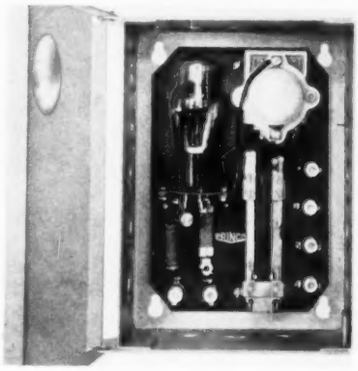


(Write for Free Catalog)

THE PALMER COMPANY
MANUFACTURERS
A.S.T.M., Laboratory and Industrial Thermometers
2511 Norwood Ave., Cincinnati, Norwood, Ohio
Canadian Plant: King & George St., Toronto

Control-system Relays

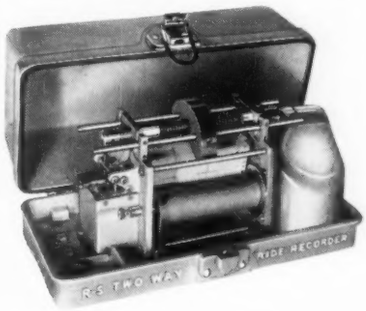
Two new series of relays are announced, both designed for instrumentation applications: (1) *Electronic* relay for use with instruments of extremely



delicate contact: sensitive mercury-in-glass thermostats, microampere relays, resistance-type photocells, etc. A current of 5 microamps through contacts suffices to operate relay, which will control a maximum current of 30 amps, 110 volts a.c. Unit measures 5" × 5" × 3½" without case, operates on less than 10 watts, is available only for use with 110 volts a.c. or d.c. (2) *Resonant* relay, for use in connection with mercury-in-glass thermostats and thermoregulators, operating on a low value of a.c. and said to insure instruments against failure for a life of from 2 to 7 million operating cycles. Unit is of balanced armature type, operating in any position, is especially suited to laboratory, where comparatively noiseless operation is advantageous. Maximum capacity of 6 amps, 110 volts a.c.; furnished with three sets of cords—for line, load and thermostat connections. Available in either small knockout boxes or black Bakelite cases, 3" × 5" × 2½". A 6-amp. built-in toggle switch is optional in the latter type.—*Precision Thermometer & Instrument Co., 1434 Brandywine St., Philadelphia, Pa.*

Ride Recorder

Similar in principle to two-component recording accelerometers, vibrometers and "riding comfort" recorders, new "R-S Two-way Ride Recorder" was developed



especially for use in connection with merchandise shipped by freight: division of chart zones, selection of chart speeds, availability of marking device remotely operated from telegraph key, etc., and other features distinguish this new instrument from maker's other ride recorders.—*The Impact Register Co., 510 N. Neil St., Champaign, Ill.*

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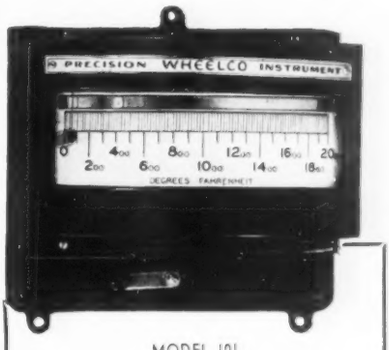

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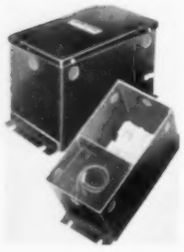

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Suitable for experimental or research work, or demonstrations, new "Type 1224A" comprises phototube, thermionic amplifier, resistor, potentiometer, capaci-

tor and small electromagnetic relay. Wiring diagram is printed on base. All wire, terminals, brackets, and screws are included. Furnished as a kit for student assembly, or completely assembled ready for use. User can adapt the unit to controlling signals from moving devices, or starting and stopping apparatus; as a limit switch and for simple photometric measurements; also as a sensitive electronic relay (1 or 2 microamps in input circuit control a 100-watt load) for controlling constant-temperature baths with a mercury thermostat. — *G-M Laboratories, Inc., 1732 Belmont Ave., Chicago, Ill.*

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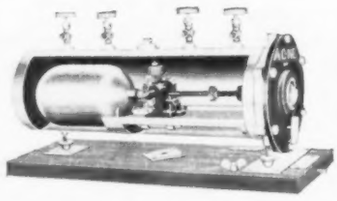
To ameliorate legibility of currently-used road maps is purpose of a new magnifier mounted in zylonite with a pair of hinged calipers for the estimation of distance between towns. Combination is about 2" in diameter, comes in full-leather pocket case. — *Bausch & Lomb Optical Co., Rochester, N. Y.*



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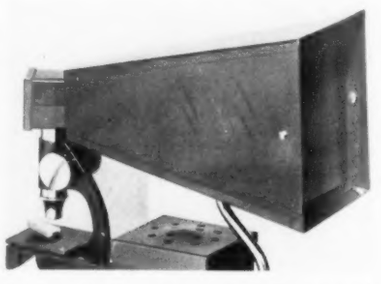

magnified object image may be measured. On this scale, each millimeter division is about an inch long. Microscope stage is illuminated by a powerful projection lamp and reflecting condensing optical system so that in addition to regular 25× projection on ground-glass screen, enlargements of greater size may be made by using an external screen in a darkened room. Dimensions, 9½" × 4¼" × 15¼" high.—*Henry Paulson & Co., 37 S. Wabash Ave., Chicago, Ill.*

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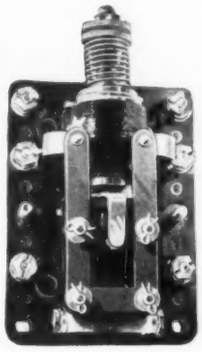
Overload Relay

New overload relay is available for use on either d-c. or a-c. Contacts are rated 30 amps at 110 volts a-c., 20 amps at 220 volts a-c., 6 amps at 110 volts d-c. and 3 amps at 230 volts d-c. on non-inductive loads. Unit is somewhat similar to maker's mechanical latch-in electrical reset relays. Contacts can be arranged to be closed manually or by means of a voltage-operated coil and when closed, they latch closed. Latch is adjusted to pick up and open contacts when current in overload coil reaches proper value. This setting is adjustable by knurled nut at top, over a range of 2 to 1.—*Struthers Dunn, Inc., 125 N. Juniper St., Philadelphia, Pa.*



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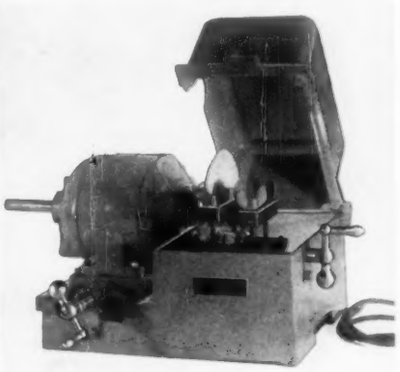
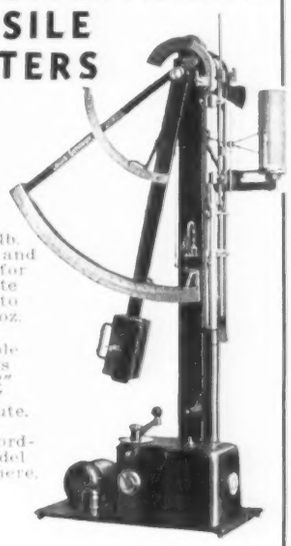
Developed for metallographers, mineralogists, etc., this unit employs a 3450-r.p.m. motor driving thin abrasive wheels or diamond-charged metal disks for sectioning materials subjected to microscopic examination. Saws or wheels 6" to 9" in diam. permit sectioning specimens up to $3\frac{1}{2}$" wide and 4" thick.—*Mico Instrument Co., Cambridge, Mass.*



SCHOPPER Precision
TENSILE TESTERS



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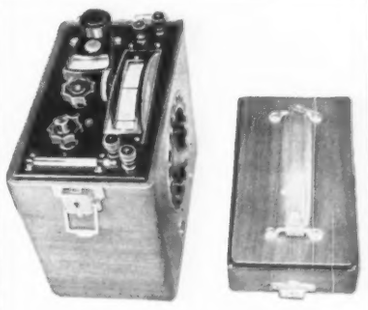

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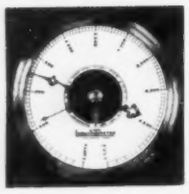

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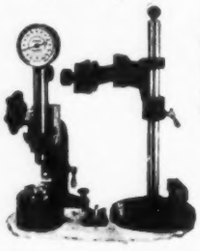

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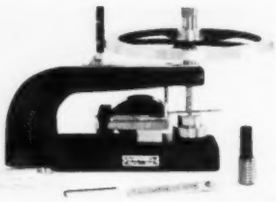

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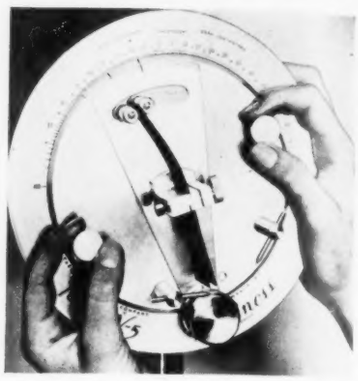
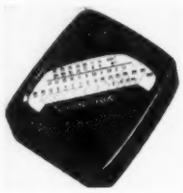


wire. Shear accessory (not illustrated) blanks out test specimens accurate to size, insuring against dimensional errors associated with single shears. Both units are light, portable, can be used in laboratory, office or plant, by those without previous technical experience. Features: Metric calibration with continuous scale from 0-2000 gram-centimeters; bearings sealed in lubricant for years of service without further attention.—*Taber Instrument Co., North Tonawanda, N. Y.*

Photoelectric Exposure Meter

"Photrix" exposure meter can be worn fastened to wrist, leaving both hands free, or held in hand like any other. It has no computer dial: function of computer is performed by arrangement of scales on main dial. Sensitivity: readings are said to be obtained at light levels so low as to require 30 sec. exposure at *f*:11. Light intake is located at right angles to dial. "Electrocell" photo-element is recessed in the Bakelite casing to restrict angle of light incidence and tilted downward to exclude top light influence. Dimensions "of a cigarette lighter," $2'' \times 2\frac{1}{2}'' \times \frac{13}{16}''$.—*Intercontinental Marketing Corp., 8 W. 40th St., New York City.*



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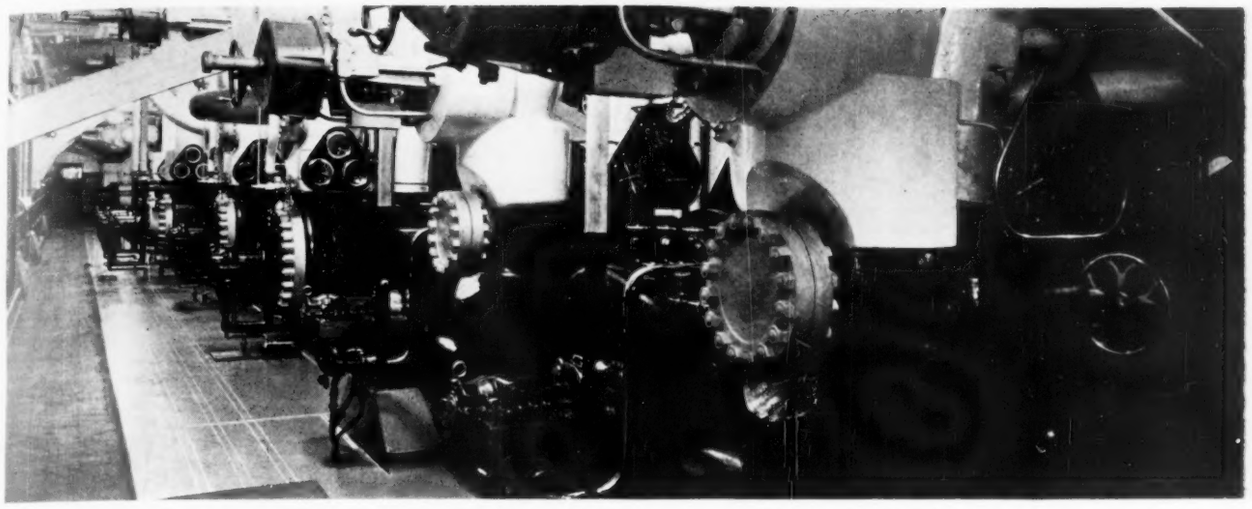


Boiler feed and booster pumps controlled from central board shown on front cover and next page

Ford Power Plant Instrumentation

In Five Articles, Specially Written for *Instruments*

2—Boiler Feed Instrumentation

By W. W. DULMAGE

Power Department, Ford Motor Co., Dearborn, Michigan

LOGICALLY following last month's article on boiler room instrumentation at River Rouge, the information which follows will confine itself to instrumentation as regards the boiler feed pumps.

Boiler feed control is centrally located on one panel board, like the controls of any one boiler as described last month. The panel includes complete metering and control equipment for the automatic control of the feed water supply. The metering equipment includes: (A) ten vertical-edgewise flow indicators, indicating the rate of flow of each pump; (B) three round-chart recorders for recording (1) the discharge pressures of the booster and boiler feed pumps, (2) the flow of the re-heat condensate, and (3) the level of the re-heat condensate in the low capacity tank. Also mounted on the panel board are individual tumbler switches for each pump. These are two-position switches, one for complete automatic control and one for manual (push-button) control.

Feed water pumping equipment for the three high-pressure boilers consist of five booster feed pumps and five boiler feed pumps, also one re-heat condensate pump. The booster pumps take water from the de-aerator heater at 35 lbs. absolute and pump it to a header at 780 lbs. absolute. The boiler feed pumps take the water at 750 lbs. absolute after it has passed through the cross-over and high-pressure heaters, and raise it 1530 lbs. absolute, pumping it directly to the boiler. These pumps are divided into two separate groups: Booster pumps Nos. 1-2-3, boiler feed pumps Nos. 1-2-3 and the re-heat condensate pump supply feed water to boilers Nos. 1-2-3. Booster pumps 4 and 5, and boiler feed pumps 4 and 5, supply water to No. 5 boiler.

All pumps are controlled from one master panel board and, through motor-operated valves, the pumps may supply one individual boiler, or they may all feed into a common feed water header.

Booster Pumps.—Booster pumps Nos. 1-2-3 have a rated capacity of 1480 g.p.m. each, at 1720 r.p.m against a head of 1920 feet. Two of these pumps are driven by a 1000-h.p. motor; the third is driven by a steam turbine. Numbers 4 and 5 have a rated capacity of 2535 g.p.m. each, at 1770 r.p.m. operating against a total head of 1771 feet. Both pumps are driven by 1440-h.p. motors.

Boiler Feed Pumps Nos. 1-2-3.—Each of these boiler feed pumps has a rated capacity of 2800 g.p.m. at 1770 r.p.m., operating against a total head of 2300 feet. The pumps are driven by 1560-h.p. motors.

BOOSTER PUMP CONTROL

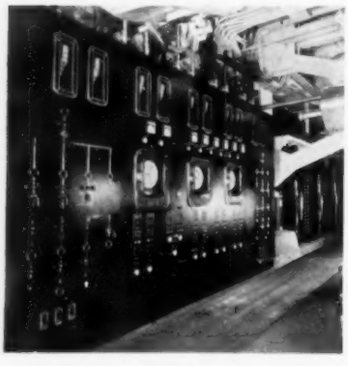
The control for the boiler feed pumps is only required to maintain a constant discharge pressure, whereas the control for the booster pumps must also maintain proportionate flows from each of the pumps in service.

An electric contact type automatic control is provided for each pump, which makes contacts for either "more" or "less" to each pump which is operating, if the header pressure is respectively low or high, or if the flow from a particular pump is less or more than that of the other pumps in service. The impulses are transmitted to electric-motor type control drives which positively operate the cam switches, or the turbine governor—as the case may be, to vary the pump speed. Tumbler switches are provided which have two positions: in one position the contactors operate automatically and, in the other, control is by hand from push buttons.

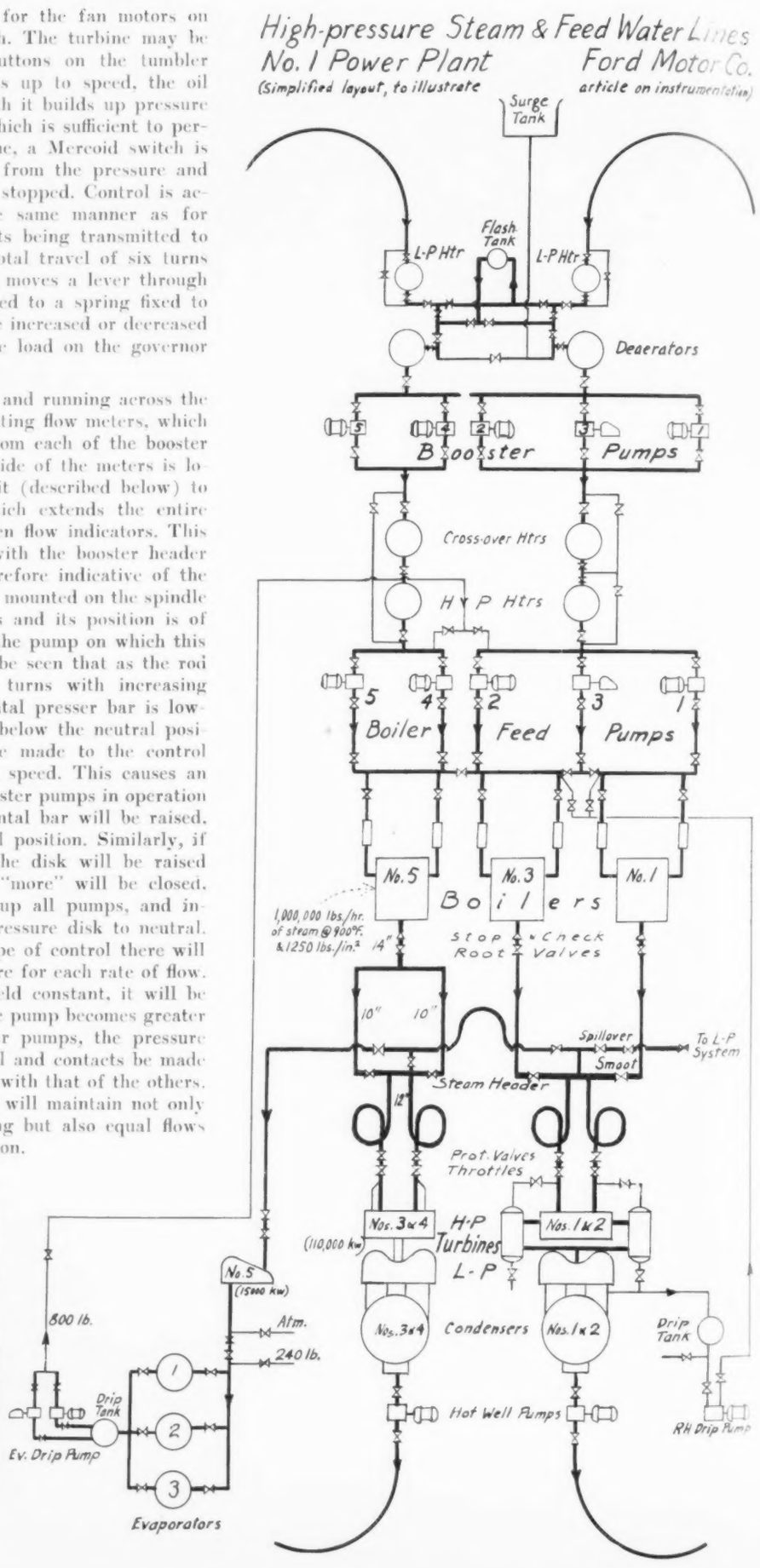
The motor-driven pumps are started and stopped by means of switches on the pump control panel, which are

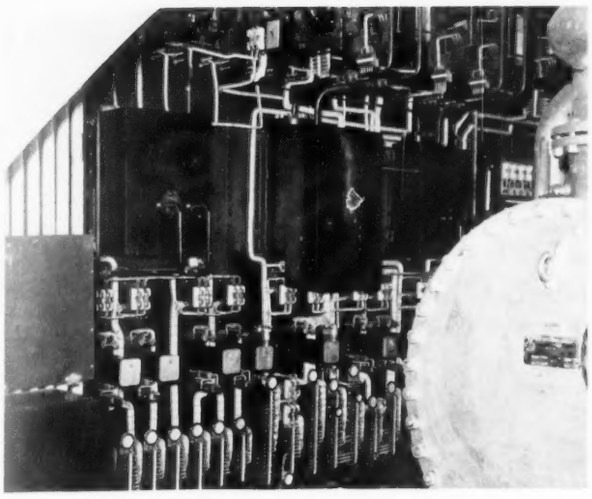
similar to the control switches for the fan motors on the boilers, discussed last month. The turbine may be started or stopped by push buttons on the tumbler switches. When the turbine gets up to speed, the oil pump which is built integral with it builds up pressure and when this reaches a point which is sufficient to permit proper control of the turbine, a Mercoid switch is tripped by a Sylphon operated from the pressure and the auxiliary oil pump motor is stopped. Control is accomplished by contactor in the same manner as for motor-driven pumps, the contacts being transmitted to the control drive which has a total travel of six turns and, through a worm gear unit, moves a lever through 45 degrees. This lever is fastened to a spring fixed to the governor lever, and hence the increased or decreased tension on this spring varies the load on the governor and varies the turbine speed.

Located on the upper portion and running across the pump panel board are ten indicating flow meters, which indicate the rate of discharge from each of the booster and boiler feed pumps. At one side of the meters is located a power type pressure unit (described below) to which is connected a shaft which extends the entire width of the panel behind the ten flow indicators. This shaft is rotated in accordance with the booster header pressure, and its position is therefore indicative of the pressure in the header. A lever is mounted on the spindle of each of the indicating meters and its position is of course relative to the flow from the pump on which this meter is installed. Thus, it will be seen that as the rod from the power pressure unit turns with increasing pressure, one end of the horizontal presser bar is lowered, throwing the presser disk below the neutral position and causing contacts to be made to the control drives on the pumps to increase speed. This causes an increased flow from all of the booster pumps in operation and the other end of the horizontal bar will be raised, returning the disk to the neutral position. Similarly, if the header pressure decreases the disk will be raised above neutral and contacts for "more" will be closed, transmitting impulses to speed up all pumps, and increase the flow, returning the pressure disk to neutral. It will be seen that with this type of control there will be consequently a definite pressure for each rate of flow. Also, with the pressure being held constant, it will be seen that if the flow from any one pump becomes greater or less than that from the other pumps, the pressure disk will be moved out of neutral and contacts be made to that pump to equalize its flow with that of the others. The booster pump control, then, will maintain not only a definite pressure for any rating but also equal flows from all of the pumps in operation.



PUMP CONTROL BOARD
(See front cover for larger illustration)





BACK OF CENTER PORTION OF PUMP CONTROL BOARD.

FEED PUMP CONTROL

Inasmuch as there is no header on the discharge side of the main high-pressure boiler feed pumps (the piping being arranged so that each feed pump is fed by but one booster pump at a time) the only control necessary is to maintain a constant pressure at the discharge side.

A helical pressure coil is connected to each of the main boiler feed lines and operates a balanced contactor. As the pressure increases or decreases, the balanced bar is moved about its pivot in the center and contacts are made on one of the movable points, energizing one of a pair of relays which in turn energizes the control drive. These same helices also each operate a Mercoid which, upon a large drop in pressure (indicating failure of a pump) makes contact to start the standby turbine-driven pump.

The pump motors and turbine are started, stopped, and controlled by push buttons on the tumbler switches indentically as described for the booster pump control. However, there being no common discharge header, when a motor-driven pump fails and the turbine-driven pump takes its place, the circuits are so arranged that the turbine pump will operate from the contactor giving impulses in accordance with the pressure in the boiler header to which the turbine-driven pump is now supplying water.

There are two power units included in the control equipment of the boiler feed pumps. They function in the same manner as the power pressure units previously described. Thus, they too maintain equal flows on all pumps in operation.

Below are listed the power pressure units and their respective units:

No. 1 operates boiler feed pumps	Nos. 1-2-3
No. 2 operates booster pumps	Nos. 1-2-3
No. 3 operates booster pumps	Nos. 4-5
No. 4 operates boiler feed pumps	Nos. 4-5

POWER PRESSURE UNITS

The power pressure device, which is used with the booster pump control to position the shaft which controls one end of the presser bars of the contactors in accordance with the pressure in the booster pump header, operates as follows:

Each unit has a pressure connection at the bottom of a cylinder in which floats a small piston, which fits the cylinder closely to prevent leakage and yet will turn freely or move up and down with small variations in pressure. This piston supports a rod, the middle portion of which serves as a pilot valve stem and the upper end of which carries a mercury cup into which is suspended a straight-walled displacer. This assembly (piston, rod and cup) is continuously rotated to eliminate static friction and therefore is equivalent to a dead-weight pressure gage tester, as the applied pressure is exactly balanced by the weight of the rotating cup and mercury and the reaction of the displacer in mercury.

The same motor which rotates this assembly drives a small oil pump to provide the oil pressure required for operating (1) the above-mentioned displacer and (2) the power piston and shaft, as follows:

When the applied pressure increases or decreases, the assembly of pressure piston, pilot valve and mercury cup rises or falls proportionately and in so doing permits oil under pressure to pass through the pilot valve to the upper or lower side of the power piston. If the pressure is increasing, the power piston will move downward, forcing the displacer deeper into the mercury. The reaction of the buoyant force of the mercury against the displacer will cause the mercury cup and pilot valve to be forced downward with the movement of the displacer until the pilot valve has closed off the oil supplied to the piston. Consequently, for each pressure applied to the small rotating pressure piston, a definite position of the power piston and displacer piston is obtained. The power piston rod carries a rack; this rack engages a pinion on the shaft; thus the position of the shaft is an accurate indication of the applied pressure. This shaft operates to move one end of the presser bar of the contactors which then give impulses to the control drives to increase or decrease pump speed in accordance with pressure variation.

RE-HEATER CONDENSATE AND HEATER DRAINAGE CONTROL

On the first 110,000 kw. unit installed, which operates at 1215 lbs. pressure with steam at 750° F., re-heaters are used after the high-pressure turbine and the steam is reheated to 600°F. (with live steam at 1215 lbs. and 750° F.) before it is passed back into the lower turbine. It is important that we maintain constant condensate level in the two steam re-heaters and in the high pressure and cross-over feed water heaters.

Inasmuch as there are two re-heaters operated in parallel, a level control tank is installed with its center line approximately at the level at which it is desired to maintain the condensate in the re-heaters and connected to the condensate discharge of both of them. By maintaining the proper level in this tank, then, the condensate in the two re-heaters will be held at the proper point.

This is accomplished by a manually operated valve on the discharge side of the drip pump. Incidentally, this condensate does not pass through any heaters but is introduced into a feed water header between the two boilers supplying steam to this turbine upon which we use reheaters.

As a final check on the control of the boiler feed water we have installed on the top portion of the boiler feed control panel board three Bourdon tube pressure gages indicating (1) the pressure of steam on the header to No. 1 and No. 3 turbine or the older 110,000-kw. unit; (2) re-heat pressure or, as mentioned above, the condensate from the reheaters being fed directly to the boiler from the drip pump; (3) the header pressure of No. 3 and No. 4 turbine or the new 110,000-kw. generator.

In conclusion, the piping layout accompanying this article will, I think, give the reader a clear picture of our feed water set-up in the Rouge Plant.

The Pyramidal Indenter Method of

The Brinell and Rockwell hardness testers were discussed in preceding articles, because (1) they represent types of testers in both of which a steel ball may be used as an indenter and because (2) in the first instrument the diameter of the imprint is a measure of hardness and in the second the measurement of hardness is based upon the increment of depth due to an increment of load from a minor to a major value (Rockwell measurements are not based upon total depth of penetration).

In both instruments, whether using a steel ball or a diamond cone as the indenter, a *circular* impression is produced.

Another form of indenter will now be discussed before leaving this general type of indentation instrument. This is the tester suggested by Smith and Sandlund[1] and now known as the Vickers Diamond Hardness Testing Machine. It was brought out first by Messrs. Vickers-Armstrong, Ltd., London.

In this instrument a square-base diamond pyramid is used as an indenter in which the apex is pointed like a pyramid with an angle of 136° between opposite faces of the pyramid. A steel pyramid indenter had been used

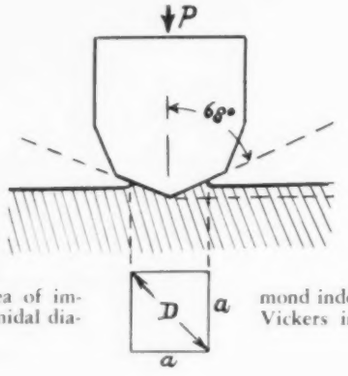


Fig. 127. Area of imprint of pyramidal diamond indenter used on Vickers instruments.

as early as 1865. The shape of the indenter is shown in Fig. 127. The shape of its imprint, which is a square, is compared with that of a steel ball in Fig. 128. The relative sizes of circular (ball) and square (Vickers) impressions on one specimen are shown in Fig. 129. In all these figures it will be seen that the length of the diagonal, D, of the square impression is the factor which is used as a measure of hardness. Usually the average of the two diagonals is taken. The diagonals are used because they are the largest dimension of the square impression and are measured by means of a microscope as shown in Fig. 128 or by means of a transparent scale as used by Le Chatelier.

In general, the degree of hardness, H, is given by the equation: $H = P/A$ where P is the load (in kilograms) impressed on the indenter and A is the area (in square millimeters) of the surface of the imprint.

In the case of the pyramidal indenter with 136° angle between opposite faces of the pyramid, the diamond pyramid hardness number is the quotient of the applied load divided by the pyramidal area of the impression. This is expressed by the equation:

$$H = \frac{2P \sin \theta/2}{D^2}$$

where P is the load in kilograms applied to the indenter, D the average length of the two diagonals, expressed in millimeters, and $\theta = 136°$. The area of the imprint may also be expressed in terms of the average length, a, of the sides of the square impression, thus:

$$\text{Area} = \frac{a^2}{\sin 68°} = \frac{D^2/2}{\sin 68°} = \frac{D^2}{1.854}$$

whence there follows:

$$H = 1.854\frac{P}{D^2}.$$

Tables accompany the Vickers machine whereby one may transform the values of diagonals directly into Vickers hardness numbers.

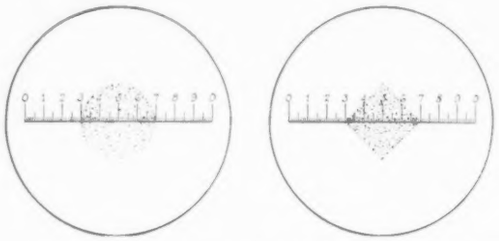


Fig. 128. An illustration from a booklet issued by Tinius Olsen Testing Machine Co., showing round and square indentations and scales of measuring microscopes or of micro-projection heads.

The general formula for hardness, $H = P/A$, applies to ball indenters and cone indenters as well as to the pyramid indenter. It was on this fundamental equation that the one for the Brinell hardness number was based. This was given in the March article as

$$H = \frac{P}{\pi D \frac{1}{2}[D - \sqrt{D^2 - d^2}]}$$

or when expressed in terms of depth,

$$H = \frac{P}{\pi d t}$$

where d is the diameter of the circular impression and t is the depth, both expressed in millimeters. When $d = t = r$, the radius of the ball, the area of the surface of the imprint is $2\pi r^2$, or half that of the ball used as an indenter. See Fig. 130. One point should be emphasized in connection with the foregoing formula. It indicates that with loads proportional to the squares of the ball diameters the same degree of hardness should be indicated by balls of various sizes when used on the same specimen. Thus:

$$H = \frac{P_1}{KD_1^2} = \frac{P_2}{KD_2^2}$$

or,

$$\frac{P_1}{P_2} = \frac{D_1^2}{D_2^2}$$

[1] R. Smith & G. Sandlund. An Accurate Method of Determining the Hardness of Metals with Particular Reference to those of High Degree of Hardness. *Proceedings Institute of Mechanical Engineers*, Vol. 1, 1922, pages 623-641. Also *Journal Iron and Steel Institute*, Vol. 1, 1925, pages 285-290; appendices, 291-294; discussions & correspondence, 295-304.

See also: V. E. Lysaght. Indentation Hardness Testing. *Canadian Chemistry and Metallurgy*, Vol. 20, December 1936, pages 380-384.

Hardness Testing

By S. R. WILLIAMS
Professor of Physics, Amherst College

It is on the foregoing basis that all the hardness testers using areas of indentations as a factor of hardness have their scales of hardness numbers estimated. That such regularity does not hold is attested by the fact that directions accompanying such instruments generally state that in giving the hardness numbers it is desirable to give the load and size of the indenter.

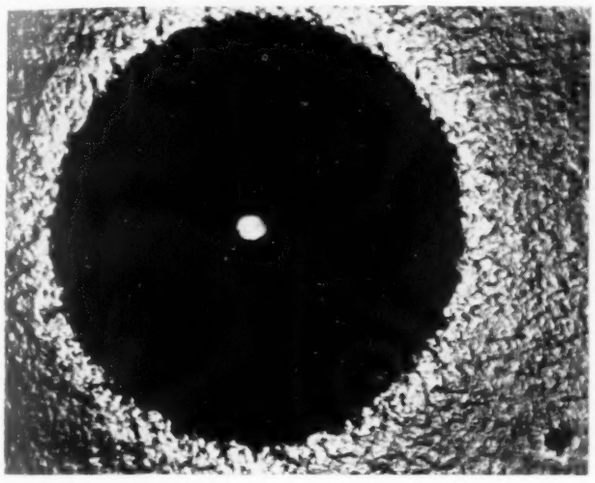


Fig. 129. Photograph of round and square imprints made by ball and pyramid indenters on one single test-piece.

TEST-PIECE—Armco ingot iron with a hardness of 81 Brinell. Highly polished before being indented. (The roughness due to the flow of metal is strikingly apparent.)
MAGNIFICATION—Approx. 9.2 ×.
ILLUMINATION—Vertical. Inclined surfaces of both indentations therefore appear black; and only the bottom of the Brinell indentation (normal to optical axis) reflects any light into camera lens.
BRINELL—Standard 10-mm. diameter steel ball and standard 3000-kg. load.
VICKERS—Standard diamond and standard 10-kg. load.
SOURCE—Test-piece prepared, and micrograph made, by Dr. Max Gensamer, Carnegie Institute of Technology, Pittsburgh, Penna., May 1938, especially for illustrating this article.
CAUTION—The indentations were purposely made close to each other at the request of *Instruments'* editor for the sole purpose of including both in one photograph. Never should they be so close in actual practice. Limits given in the instructions that come with instruments should always be observed. In this particular case the roughness due to flow of metal around the Brinell indentation makes it impossible to take an accurate reading on either of the two Vickers diagonals.

When the general formula, $H = P/A$, is applied to the cone test, then, since $A = \frac{\sqrt{2}\,\pi D^2}{4}$

$$H = \frac{4P}{\sqrt{2}\,\pi D^2} = 0.900\,\frac{P}{D^2}$$

or in terms of depth,

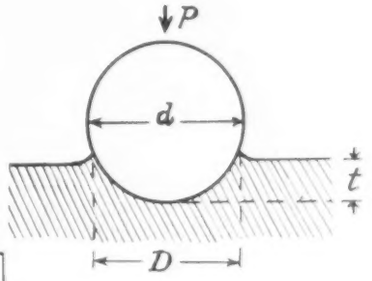
$$H = \frac{P}{\sqrt{2}\,\pi t^2} = 0.225\,\frac{P}{t^2}.$$ See Fig. 131. For a cone with an apex angle of 90° the radius r and the depth t of the imprint are equal.

The Vickers *diamond* pyramid hardness tester was developed with a view to producing a reliable and accurate means for testing metals of a high degree of hardness, for, in the case of extra-hard metals, not only does the point of the cone indenter become blunt with use and thus give false results, but also for a high degree of hardness the ball indenter ceases to give reliable results, due to a measurable flattening of the ball. This occurs even with the extra-hard Hultgren[2] steel balls. A diamond indenter, whether of spherical, cone or pyramid shape, does not suffer this deformation to such an extent.

Although diamond, the hardest material, undergoes little deformation, a recent paper by Fuller[3] shows that extraordinary care must be taken in the use of Vickers machine. If the diamond pyramid is not symmetrically set with respect to the direction of the indenting force the impression will be lopsided.

Fuller calls attention to the fact that three American pyramid indenters proved unsatisfactory in producing square imprints and it was the understanding that other laboratories were having the same difficulties. In his conclusions Fuller states that the specifications should be more specific and proceeds to make certain recommendations for improvements in the results to be obtained from a Vickers machine.

Fig. 130. Relations between diameter and depth of imprint of steel ball whose diameter is d when a load of P kilograms is impressed on the ball.



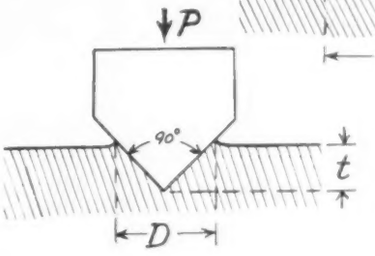


Fig. 131. Relations between diameter of imprint and depth, when a 90° cone is pushed into the metal by a load of P kilograms.

Holz has stated[4] that "In the Vickers test, it is not at all necessary to hold the test pieces in such very careful manner to obtain accurate results; the Vickers results are not affected so much by the condition of the metal surfaces in contact with the anvil or by dirt on the anvil." The author has found that in all machines with which he has worked it is necessary that the test pieces be *always* properly held if consistent results are to be obtained. In the Vickers test, if the surface to be indented is not held normal to the direction of the thrust of the spindle carrying the indenter, the imprint will be lopsided. With none of the hardness testing machines should careless, sloppy work be tolerated, particularly if the instrument is being used in research work. In all types of indentation machines, if grit or any small particles of hard foreign matter get between the surface of the indenter and the surface tested, the surface of the specimen will be broken by the particles and the imprint will not be one of plastic flow.

Since there is little deformation of a diamond indenter, even when hard bodies are being tested, the relation be-

[2] H. O'Neill. The Hardness of Metals and Its Measurement. Chapman and Hall, Ltd., London, 1934. Pages 14-16.
[3] F. B. Fuller. The Effect of Variation in Diamond Indenters Used in the Vickers Hardness Testing Machines. *Transactions American Society for Metals*, Vol. 25, 1937, pages 1198-1216.
[4] H. A. Holz. On Hardness of Metals and Metal Products. Booklet, privately printed, H. A. Holz, New York, 1937. Page 8.

tween P and A remains remarkably constant for any diamond indenter whether pyramid, cone or spherical in shape. Because there is so little deformation in the indenter of the Vickers pyramid, the hardness numbers obtained by its use are fairly independent of the load.

In general it has been recommended that in the Brinell test the load on the steel ball should be so adjusted that

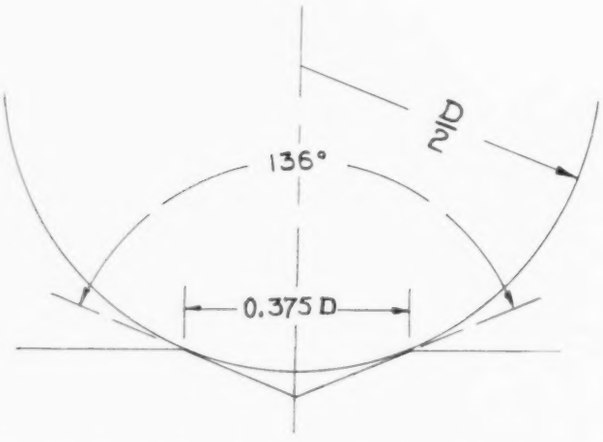


Fig. 132. Showing how the angle at the apex of the diamond pyramid indenter was determined for use in the Vickers Pyramid Hardness Tester.

the diameter of the imprint would lie between the limits of $0.25D$ and $0.5D$ where D is the diameter of the ball. The average of these limits is $0.375D$. If one draws tangents to the edge of the imprint for a circle which is the cross-section of the ball at $0.375D$, as shown in Fig. 132, the angle between the two will be 136°. It is for this reason that the 136° angle between opposite faces of the Vickers pyramid indenter was chosen. In actual tests the pyramid indenter with this angle does give hardness numbers which are in close conformity with those obtained by the Brinell test.

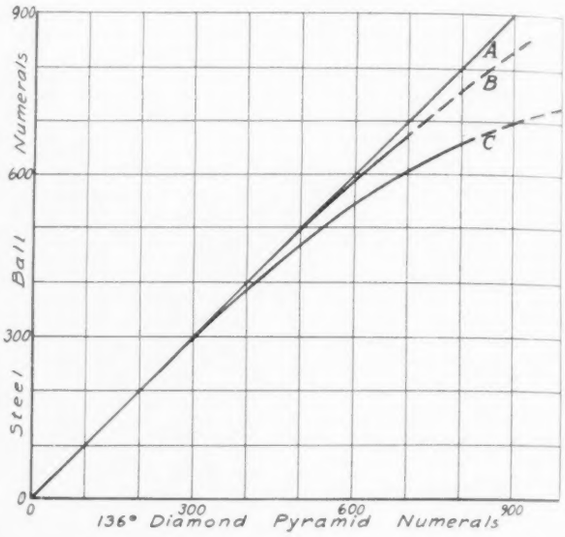


Fig. 133. Curves showing relation between Brinell numerals obtained by (A) diamond pyramid; (B) 1-cm. steel ball loaded to give an impression of diameter equal to 0.375 × diameter of the ball, and (C) 1-cm. steel ball under load of 3000 kg.

This correspondence between the hardness numbers obtained by the two methods holds only for the "softer" materials, *i.e.*, so long as the steel ball does not suffer an appreciable deformation due to the pressure applied. Between Brinell hardness numbers 500 and 600, this deformation really begins to make itself felt in comparative values. Fig. 133 shows these departures from strict proportionality between load and area of imprint as the hardness increases. When a diamond sphere is used in the Brinell machine, the comparisons become valid over a much wider range.

To Be Continued

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INSTRUMENTATION FORUM

PROBLEMS — SOLUTIONS — DISCUSSIONS

MARCH PROBLEM (No. 17). Consultants have not yet made their recommendations as we go to press. Solutions and discussions in next issue, we hope!

APRIL PROBLEM (No. 18)
CATHODE-RAY TUBE TIMER

"In connection with an application of the cathode-ray tube, I require a time base that will move the spot horizontally across the screen every one-fifth of a second, or multiple thereof, beginning always at the same edge. This transit across the screen need not be at uniform velocity from edge to edge, but all successive transits must be absolutely identical in duration. Duration should not exceed one-hundredth of a second. The beam must begin its sweep every fifth of a second (or multiple) without being off more than two or three millionths of a second."

EDITOR'S NOTES—(1) Presumably, duration to be adjustable UP TO 0.01 sec. and inquirer will frequently use a setting of a millisecond or less, for it is only at such speeds that a timing variation of 2 or 3 microseconds would matter. (2) Presumably, return trace to be suppressed.

A cursory examination of all entries sufficed to bring out that none was a satisfactory "solution."

But how many deserved $5 prizes as "discussions pointing the way"? To find out, we sent them all to Ralph R. Batcher, prominent electronic engineer, author of "The Cathode-ray Oscillograph and Its Applications" (*Instruments* serial, soon to appear in book form). We not only appointed him "judge" but requested him to send in either a "solution" or a "discussion pointing the way."

Finding no entry acceptable, Batcher declined to enter. Wrote he: "I don't know how a judge can reject all other entries and then enter a competition himself."

We insisted, requesting some constructive suggestions for this issue of our forum—"something for *Instruments* readers who may have similar problems." He finally wrote, in the nature of "Brief General Comments," the following:

By RALPH R. BATCHER

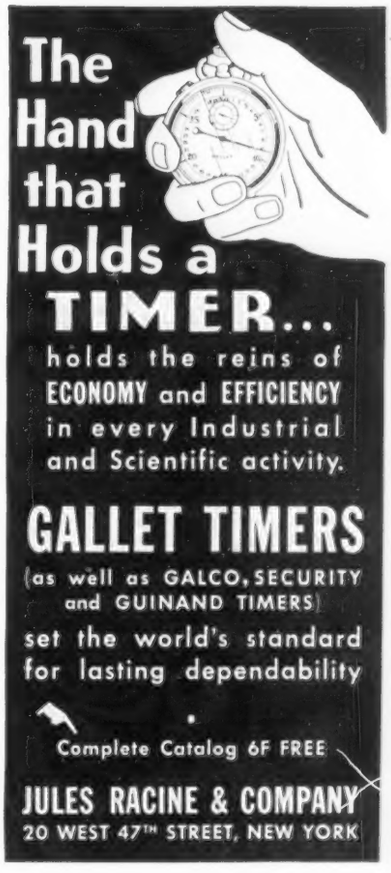
All of the contestants suggested the use of a linear sweep circuit using a Thyratron. Several actually synchronized the sweep against the surges under test, thus destroying any semblance of a "time standard base" such as was required in the problem.

An ordinary Thyratron can be driven by a standard frequency, and two contestants submitted such arrangements.

E. M. Fry, Jr. proposed a synchronous-motor-driven mirror actuating a photocell which initiates the start and stop of a Thyratron sweep.

When any duplication accuracy of a few microseconds is considered, several factors in this scheme introduce variations which were not considered by the contestants:

(1) A Thyratron does not discharge a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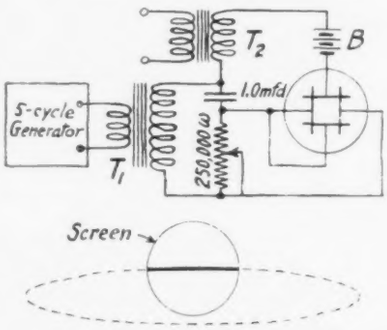
capacitor to zero voltage, but to a value which is only approximately constant. Also, leakage currents through the charging pentode during the "waiting" interval build up a floating charge so that the starting and stopping points of each sweep are not under absolute control. The intervals between successive crossings of a reference point by the spot may not be uniform. This scheme fails also to consider the flicker and variations in the darkness of the photocell chambers.

(2) In getting microsecond accuracy, too, the cathode-ray tube must be supplied with constant voltages so that its sensitivity will not be altered. The tube must be well shielded from stray fields, so that the zero position of the spot will not wander in either a random or cyclic manner.

L. R. Lankes proposed a special sweep circuit driven by a beat-frequency oscillator consisting of two crystal controlled oscillators. This was rejected because of the impracticability of thus generating a 5-cycle standard frequency. Assuming that two crystals could be readily adjusted to a 5-cycle difference, there still remains the problem of controlling their individual frequencies within close enough limits. As an example, assume two crystals with 100,000- and 100,005-cycle frequencies. To produce a standard difference frequency of 5 ± 0.000005 cycles, or a one-cycle variation in 200,000, would require each crystal to be constant within $2\frac{1}{2}$ parts in one hundred billion.

Along the lines of "constructive suggestions" it may be said that it is first necessary to operate the cathode-ray tube under constant conditions, as mentioned above.

As to the sweep circuit, all of the vagaries of a Thyratron are eliminated by applying a standard frequency of 5 cycles to an ordinary elliptical "rotator" circuit (see sketch). Enough voltage from T_1 is applied so that the major axis of the ellipse is about ten times as large as the screen and only its central



portion appears on the screen. Battery B is adjusted until the part of the elliptical trace that crosses the screen is centered. This part will be substantially linear in a relatively long ellipse, with the spot off the screen most of the time and traversing it in a single direction 5 times per second. The unknown wave can be applied to the transformer T_2. The time of traverse depends on the adjustment of the 5-cycle voltage out of generator. This can be set to give a sweep of approx. 0.01 sec. by applying a 60- or 100-cycle timing wave to T_2 and viewing its trace.

This still leaves the problem of getting a 5-cycle generator. A vacuum-tube oscillator, temperature controlled to maintain frequency and output voltage stability can be built. After a rough calibration, the actual temperature can be varied to make the final adjustment of the frequency. Calibration can be made by applying the amplified "ticks" of a high-grade watch or chronometer to transformer T_2, so that a surge will appear on the screen: if the frequency is not exactly the same as the ticks, the surge will appear to "walk" across the screen. It is doubted that a standard generator can be pre-calibrated by the manufacturer and guaranteed to remain accurate if transported to another locality, where such factors as barometric pressure, etc., might affect calibration. An accuracy of one part in a million is the same as one cycle variation in a little over two days. The standardizing chronometer can be checked frequently during that interval by standard time signals. This system accuracy depends on the frequent calibration check with the chronometer, since apparatus constancies of the stated order are not ordinarily obtained with simple apparatus. It may be mentioned that watch comparators or rate-recorders are commercially produced which employ a frequency standard obtained by a crystal oscillator, with a low-frequency drift, working through a six-or seven-stage multivibrator which reduces the frequency to five cycles, and still retains the initial percent variation of the original crystal. I remember seeing watch comparators reported in *Instruments* when they came out some years ago, but readers need only visit the nearest modern jewelry and watch repair shop.

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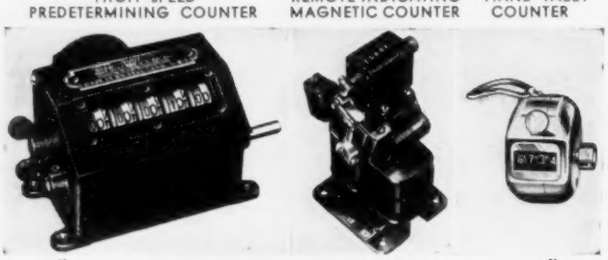
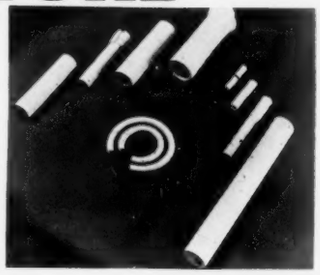


Veeder-Root Inc.
HARTFORD, CONNECTICUT, U. S. A.
Offices in Boston, Chicago, Cincinnati, Cleveland, Detroit, Greenville, S. C., Los Angeles, New York, Philadelphia, Pittsburgh, St. Louis, San Francisco, Montreal, Canada, Buenos Aires, Mexico City, London, Paris, Tokio, Shanghai, Melbourne.

RESISTORS . . .

WHY WE MAKE OUR OWN



REFRACTORIES

A wire wound resistor is only comprised of three elements . . . the refractory, the wire and the enamel. Each must expand and contract in relation to the other two in order that changes of temperature do not cause damage. By careful selection of the basic materials and the controlled production of the resistor refractories, Ward Leonard is enabled to match refractories to both wire and enamel thus giving Ward Leonard Resistors the long life that has always characterized them.

Send for Bulletins of Interest

WARD LEONARD ELECTRIC COMPANY
38 South Street, Mount Vernon, N. Y.
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